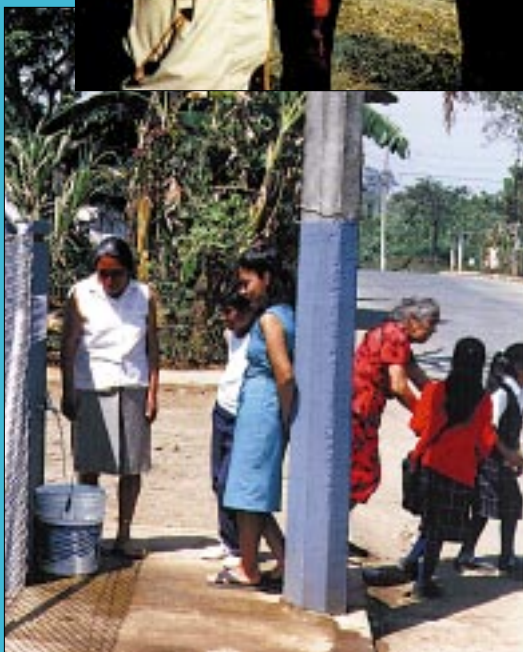




Providing Solutions for a Better Tomorrow

A Progress Report on U.S. EPA's Drinking Water Treatment Technology Demonstrations in Ecuador, Mexico and China

Testing Water in China



Providing Access to Treated Water in Mexico



Drinking Disinfected Water in Ecuador

“It has been estimated that 35 percent of all deaths in developing countries are directly related to contaminated water.”

Without appropriate treatment mechanisms in place to remove dangerous chemicals and disease-causing microorganisms from a water supply, taking a drink of water can be very risky. To reduce these risks, researchers at the U.S. Environmental Protection Agency’s (U.S. EPA) National Risk Management Research Laboratory have been developing and refining drinking water treatment technologies for decades through internal research efforts and partnerships with the academic sector and private manufacturers. Their successes have resulted in many of the current drinking water treatment technologies in use worldwide. However, a significant challenge remains: How can we get the best possible water treatment technologies in place to reduce the threat of water-related illness in less developed countries?

One important approach for meeting this challenge is the U.S. Technology for International Environmental Solutions (U.S. TIES) program. U.S. TIES, a component of President Clinton’s Environmental Technology Initiative, was initiated in 1994 to match pressing environmental problems in other countries with the suppliers of proven and cost-effective environmental technologies in the U.S.

Once their proposals were approved and funded under U.S. TIES, scientists and engineers at the National Risk Management Research Laboratory became “drinking water ambassadors” to several countries. In this role, the Agency’s researchers developed partnerships with government and health

officials as well as utility operators at proposed sites with the following goals:

- Thoroughly assessing the contamination risks to drinking water supplies
- Considering current and future drinking water needs at each proposed site
- Matching most appropriate, low-cost drinking water treatment technologies with specific demonstration sites
- Objectively brokering the purchase and operation of chosen technologies at the various sites
- Assisting in start-up and operation of the selected “demonstration” treatment technologies
- Monitoring demonstration technology effectiveness
- Assessing available health records before and after treatment technologies begin operation to evaluate the positive impact of installed demonstration treatment devices

Final performance results from each project will be available within two years. As drinking water treatment technologies are proven at the various demonstration sites, it is hoped that decision makers in those countries will choose to expand the use of such technologies and develop lasting relationships with the participating American technology vendors. Descriptions of demonstration projects in Ecuador, Mexico and China follow.



Technology representatives Lino Gallo (left) and Chip Landman (kneeling) explain the operation of a point-of-use water treatment unit to regional and local health staff in Ecuador. Landman noted, “The U.S. TIES program is certainly the most result-oriented, risk-reducing government program Watersolve International, LLC, has ever been associated with. The program has afforded our company an opportunity to collaborate with U.S. EPA and foreign authorities to help prove the effectiveness of U.S. technology in reducing waterborne disease — and saving lives — in developing locations throughout the world.”

Ecuador

The intent of this project is to reduce diseases caused by waterborne pathogens through the use of U.S. technologies that can be purchased, operated and maintained at a reasonable cost. Complicating factors include sporadic availability of electricity (for treatment devices and maintaining continuous positive pressure in the distribution system), inconsistent system maintenance, and difficult terrain. EPA's governmental partners in the Ecuador project are the U.S. Agency for International Development and the Manabi Provincial Water Authority. Hagler Bailly, Inc. and Watersolve International, LLC, are the American companies providing consulting services and drinking water treatment equipment respectively.

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Manta

In this coastal town, the demonstration site is a 220-bed hospital. Here, when available, drinking water is provided by the city distribution system; additional water is often trucked in. From these sources, water is piped to large holding tanks, and

disinfected by mixed-in chlorine. Even with a capable engineering staff, drinking water quality remained poor. With diarrheal diseases most prevalent at this hospital, patients often brought drinking water with them from home.

Problems: Potential problems included a questionable supply and resuspension of settled-out contaminants during the chlorine mixing process. Intermittent power outages meant that water pressure was not continuous — allowing siphonage of surrounding contaminants into distribution pipes (see figure at right).

Solutions: A drinking water package plant — employing filtration and ozone disinfection as well as chlorine addition to maintain a residual disinfectant in the water — was installed to ensure that water being distributed throughout the hospital would be contaminant-free. Several members of the hospital staff were trained by the equipment manufacturer to maintain the package plant. Weekly cleaning of the storage tanks will help prevent resuspension of settled-out contaminants.

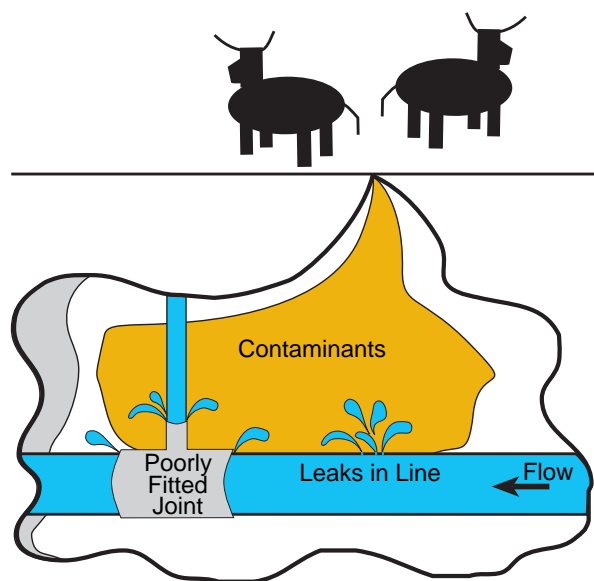
Monteoscuro

This community of 150 families is primarily served by well water drawn and stored in a 13,000 gallon storage tank. Most of the residents boiled their drinking water for disinfection prior to the installation of the demonstration drinking water

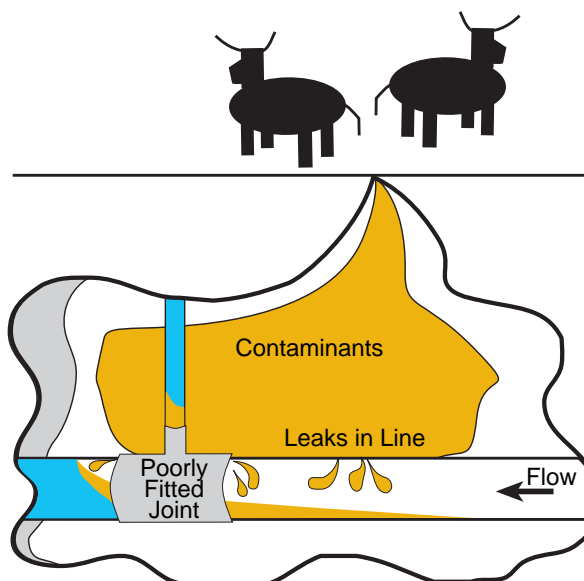
EPA microbiologist Hector Moreno (front center) performing a bacteriological assay in Monteoscuro, Ecuador. Here, samples were taken at the drinking water source, immediately outside of the treatment plant, and ten houses away from the plant to monitor disinfection effectiveness.



Positive Pressure in Water Lines



Negative Pressure in Water Lines



An uninterrupted power supply to pumps enables the maintenance of a “positive pressure” in a drinking water distribution system (above left). Should leaks occur in connections (e.g., poorly fitted joints) or pipes, treated water (in blue) under positive pressure would flow out of the system at the point of the leaks — with no contamination of the drinking water remaining in the lines. However, when a power supply is interrupted, pumps can no longer operate and a “negative pressure” or vacuum can occur in the distribution line (above right); contaminants (brown) may then be drawn into the system and distributed to consumers.

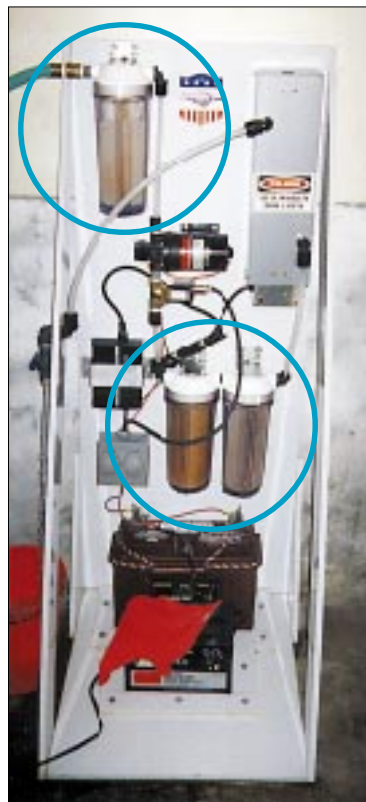
treatment technologies. Medical records at the local clinic showed that diarrhea was a very common illness among the residents.

Problems: The source water has a high concentration of particulate matter (favoring the presence of “pathogens” or disease-causing bacteria, viruses and protozoa). Animal and human wastes are potential sources of the pathogens.

Solutions: A backwashable multimedia filter has been installed to reduce particle presence; ultraviolet (UV) disinfection, in operation whenever the water is pumped from the well, has significantly reduced the risk of pathogens in the filtered drinking water. Finally, a chlorine residual is maintained in the distribution system to help guard against contamination of the water after UV disinfection.

La America

This community receives spring water stored in an uphill 15,000 gallon storage tank. Water is distributed to the 56 homes connected to the water supply system during a two-hour period every two days. Residents refill their individual storage tanks



This treatment unit was installed at the La America clinic with untreated water entering through the green hose at top left. The filters (circled in blue) are set up in order of decreasing porosity. The top filter traps particles larger than 30 micrometers in diameter. The bottom two filters, with 5 micrometer (left) and 1 micrometer porosity, remove bacteria and protozoa. Brownish yellow materials visible on these filter cartridges are trapped contaminants. UV disinfection occurs in the grey box at top right.

La America demonstration site. (a) Local clinic records are being reviewed for incidence of illness and death caused by diarrhea. (b) Drinking water source for LaAmerica. (c) Water storage tank for La America clinic. (d) One of the point-of-use treatment units installed in La America. Blue cannister contains an easily replaceable filtration cartridge.



during this period; a negative pressure inside the distribution lines is likely during off hours (see figure at top of previous page). Residents find a yellow slime on the bottom of their home storage tanks when the water is allowed to settle. Records from the local health clinic indicate that diarrhea is the most common disease; residents have suffered from such parasites as *Entamoeba histolytica*, *Giardia*, and *Ascaris lumbricoides* (worms).

Problems: The source water (see picture “b” above) and the holding tank are susceptible to contamination. Periods of negative pressure in the distribution system increase potential for contaminants to enter into the lines.

Solutions: To reduce potential contamination, the spring was contained in a concrete structure. Three point-of-use devices were installed because there was no potential for a central treatment facility in this community. These devices, employing filtration and UV and/or iodine disinfection, were installed in several locations to facilitate access to treated water. Filtering out contaminants and disinfecting the drinking water at the point of use can reduce risks associated with contaminants present in the source water and those entering the distribution lines. While not as convenient as having a contaminant-free drinking water supply in each household, access to

the three sources of treated water is expected to greatly reduce exposure to diarrhea-causing parasites in this small village.

Mexico

Demonstrations of drinking water treatment technologies in Mexico are being funded under an



Poster used in a Mexican clinic to explain measures to take when stricken with diarrhea.

interagency agreement between the U.S. EPA and the U.S. Department of Agriculture (USDA) Foreign Agricultural Service. After considering needs and willingness to cooperate, three demonstration sites were identified. Health records indicate that gastrointestinal disease is prominent at the sites; doctors and nurses in clinics serving the selected areas suspect that contaminants in the drinking water are the primary cause of the noted illnesses. Fearing the presence of diseases such as cholera, clinics post warning signs and sets of instructions to educate residents on symptoms and proper sanitary practices.

Aimed at cost-effectively reducing microorganism-related disease at the selected sites, this project involves numerous partnerships. Government partners include U.S. EPA and USDA, as well as local Mexican officials and the Comision Nacional Del Agua. The American Commonwealth Management Service Company has teamed with a Mexican host company to install and operate the chosen technologies. IT Corporation and MIOX Corporation are the American manufacturers of the drinking water treatment technologies to be demonstrated.

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Ixhuacan de los Reyes

This demonstration site is a community of 5,500 people with an estimated water demand of 85 gallons per minute. Water is drawn from a river and piped into a presedimentation tank, a sedimentation basin, and then a stone storage tank. Prior to installation of the demonstration treatment devices, disinfection (chlorination) occurred at the point where water left the stone storage tank for distribution to the town.

Problems: The river source suffers from high turbidity during heavy rains. High levels of microorganisms are present in the source water. System capacity must be expanded to accommodate anticipated increasing water usage.

Solutions: Multimedia filters were installed followed by bag filters and a chlorination unit. The Vera Cruz state government has shown a great deal of interest in the drinking water treatment demonstration project at Ixhuacan. Improved drinking water quality is part of an overall plan to encourage residential and industrial growth in this part of Mexico.



Drinking water treatment and storage facility at Ixhuacan, Mexico.



In the top photo, USDA representative (left) and Vera Cruz state governor (2nd from left) viewing treatment technology at the dedication ceremony in Ixhuacan. Plaque (inset) honors contributions by the U.S. EPA and USDA. At bottom, the governor officially opens operations at the Ixhuacan treatment facility.



Treatment facility and storage unit installed at La Luz, Mexico demonstration site. Drinking water is provided to nearby elementary school and also made available to community residents.



Professor at F.I. Madero School in La Luz. Newly installed fountains will help provide students access to treated water from the U.S. EPA demonstration facility at top of page.

Francisca I Madero Public Elementary School

The school is located in a small suburb near Cordoba, Mexico, and serves approximately 300 children. The water supply for the school is a hand-dug well, covered but not sealed. Water is pumped to rooftop cisterns to provide pressure to the distribution system within the school. Prior to installation of the demonstration treatment technology, children were advised to bring water or beverages for consumption from their homes.

Problems: Unsealed well cover and rooftop cisterns were open to contamination. A direct supply of disinfected water is needed at the school.

Solution: An electrolyzed salt-brine system was installed to disinfect the water supplied directly to the school. A water tap was also installed to provide community access to the treated drinking water. The treatment devices that were installed at the school and in the community are expected to greatly reduce the risk of exposure to waterborne pathogens.

China

Safe drinking water has become a high environmental priority in China. After raw water characteristics were considered, three demonstration sites were initially chosen where various treatment technology configurations would be installed. These systems are aimed at removing high levels of industrial organic contaminants, heavy metals, hardness, iron, nitrate, fluoride, and microbial contaminants from drinking water without generating large amounts of contaminated residual (as can be found with conventional treatment approaches). Through this project, U.S. EPA will not only serve as a catalyst for expanding the drinking water technology market, but will gain valuable performance data for a variety of drinking water contaminants. In turn, China will gain knowledge regarding the use of effective new technologies as well as improved public health. Four demonstration sites are currently operating.

Government partners include U.S. EPA and USDA, as well as central, provincial, and local Chinese officials. American consulting and equipment vendors include Ecowater, IT Corporation, and the American Commonwealth Management Services Company. Installed technologies include tray and

packed tower aeration (for removal of volatile organic chemicals), granular activated carbon (for removal of organic chemicals), multimedia filtration (for removal of various suspended solids), ion exchange (for removal of inorganic ionic species like calcium and magnesium ions), and reverse osmosis membranes (for removal of dissolved solids). An international workshop is planned in Beijing for Spring, 1999, to disseminate results and encourage further collaboration among drinking water experts.

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Huantai Village

In a small agricultural village outside Zibo City, a system with shallow wells was chosen as a demonstration site. Although no medical data were available, the drinking water was found to have high fluoride and nitrate levels with trace levels of volatile organic contaminants. Low levels of ingested fluoride are beneficial. The extremely high fluoride levels found in the drinking water source for this community, however, had caused poor dental conditions and skeletal problems. While microorganisms were not found to be a significant risk in this aquifer, residents disinfected their drinking water by boiling it.

Problems: Local drinking water supply contains unhealthy levels of natural and man-made contami-



Use of locally manufactured materials presented an unexpected problem. Translucent plastic piping exposed to sunlight lead to heavy biofilm growth (green areas in two leftmost columns and inset) in a treatment system found in China.



U.S. EPA's James Goodrich (back left) discussing demonstration technology activities with the mayor of Zibo City (right) and a technical expert (front).

nants. Many residents transported their drinking water from a less contaminated aquifer nearby which may be unable to sustain this additional drawdown. *Solution:* To ensure the safety of drinking water drawn from the local groundwater supply, a 10 gallons per minute treatment train was installed; treatment processes include tray aeration, multimedia filtration, granular activated carbon (GAC), and reverse osmosis. The system has been operating well since January 1997.

Beijing's First Bottled Water Plant (Haidian District)

This government owned facility has had problems producing contaminant-free bottled water. The existing treatment train includes six steps. The plant draws water from a deep well with low levels of industrial contaminants, moderate hardness and nitrate concentrations.

Problems: Bottled water production, marketed by the Chinese government as a safe alternative to potentially contaminated wellwater, has suffered because of treatment difficulties. Source water is hard and moderately contaminated with natural and man-made contaminants such as formaldehyde, nitrates, chromium, and strontium.

Solutions: A three-step pilot scale treatment train installed in September, 1997, is operating well near the existing plant. This technology, employing multimedia filtration, ion exchange, and GAC, has an output of 10 gallons per minute (as compared to the 70 gallon per minute output of the existing plant).



This component of the demonstration treatment technologies is an 'air stripper' used to remove volatile organics from the water. Its packing (visible in the porthole and inset photo), white when newly installed, has been fouled due to high iron concentrations.

Zibo City Water Supply and Wastewater System, Dawu Aquifer

This demonstration is aimed at improving drinking water distributed to 2.5 million city residents. The demonstration technology has been put in place on a pilot scale, operating at 10 gallons per minute.

Problems: The groundwater has been contaminated by oil refinery and plastics industry wastes. High hardness and iron levels make treatment of the organic contaminants very difficult. Volatile organic contaminants include benzene, toluene, and xylene in the milligrams per liter range. Contaminant levels have proven to be extremely variable.

Solution: Because of the extremely variable contaminant levels, substantial modifications have been made to the original treatment train as well as repair to the system following a recent typhoon. The system includes two iron filters, multimedia filtra-

tion, packed tower aeration, GAC, and reverse osmosis membranes.

Due to the success of these demonstrations (e.g., significant reductions in contaminant levels in the treated drinking water) and relationships developed between the government partners, a fourth system was installed in July 1997. The 20 gpm system was purchased by Zibo City's Water Supply and Wastewater Utility from Watersolve International, LLC, a Colorado Springs based company, to further treat water for a new housing complex in Zibo City, China. The system is composed of GAC, cartridge filtration, UV pre-disinfection, reverse osmosis membranes, and ozonation. This purchase gives testimony to the effectiveness of the earlier-demonstrated technologies. Also significant is that Zibo City purchased the technology from an American vendor *without* U.S. government mediation — fulfilling a long-range objective of the U.S. Technology for International Environmental Solutions program.

Solutions for a Better Tomorrow

Granular activated carbon...reverse osmosis...aeration...ultraviolet irradiation.... Drinking water treatment technologies have become very advanced in the last century. While these advancements can be heralded as lifesavers throughout much of the world, municipalities in many countries can afford only the most economical water treatment technologies. Equally important, these towns and villages cannot afford to buy and operate treatment units that are inappropriate for their specific needs.

U.S. EPA's National Risk Management Research Laboratory, drawing from decades of research and development successes, is committed to sharing its expertise. In partnership with other U.S. agencies and American manufacturers of cost-effective technologies, the U.S. EPA is demonstrating that drinking water supplies can be made safer at reasonable costs.

For additional information about U.S. EPA's risk management research, visit the following internet web site:

<http://www.epa.gov/ORD/NRMRL>

This publication was written and produced by Patrick Burke of USEPA's National Risk Management Research Laboratory (NRMRL) within the Office of Research and Development. Contributors and reviewers include Robert Clark, Benjamin Lykins, James Goodrich, and Hector Moreno of NRMRL's Water Supply and Water Resources Division. Additional comments were provided by Lino Gallo of Hagler Bailly, Inc. and Chip Landman of Watersolve International, LLC. All photographs were provided by NRMRL's Water Supply and Water Resources Division.

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